SM. Gill

National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No. NAS-5-9299

ST — LPS — 10459

ON THE NATURE OF VENUS' CLOUD LAYER

by
A. E. Basharinov
V. G.Kutuza

(USSR)

18 MARCH 1966

ST — LPS — 10459

ON THE NATURE OF VENUS' CLOUD LAYER*

Astronomicheskiy Zhurnal
Tom 43, vyp. 1, 149-153,
Izdatel'stvo "NAUKA", 1966

by A. E. Basharinov
V. G. Kutuza

SUMMARY

The hypothesis of the presence of overcooled water droplets in Venus' cloud layer has been verified by extrapolation in the 8 mm wavelength of absorption; these data were obtained from those on the phase course of radiobrightness temperatures, and then extrapolated to microwave and centimeter bands.

It is shown that the spectrum values of radiobrightness temperatures, obtained at extrapolation, agree satisfactorily with the measured values of radiobrightness temperatures on the night side of Venus.

The water content in the cloud layer is estimated to be of the order of 0.1 — 0.3 g/cm^3, whereas the absorption in the layer does not exceed 1.5 db in the centimeter band and is less than 5 db in the microwave band for wavelengths exceeding 3 mm.

**
** **
**

The questions of the nature of Venus' cloud layer were discussed in [1 – 8] in regard to the interpretation of optical observations and observations of radiobrightness temperatures of planet's night side.

Because of discrepancies between the computed and the experimental data, the hypothesis of the water-droplet nature of the clouds did not find corroboration in the works just mentioned.

---

* O PRIRODE OBLACHNOGO SLOYA VENERY

On the basis of analysis of the spectrum of Venus' radiobrightness temperatures the assumption was made in [10] of clouds composed of droplets of hydrocarbon compounds having a relaxation time of dipole molecules of the order of $3.5 \cdot 10^{-12}$ sec.

Detailed data on Venus' emission in the microwave band, obtained in 1963-1964, and the refining of information on the absorption spectra of water droplets provide the possibility of additional conclusions concerning the nature of Venus' clouds.

Further consideration is conducted appropriately to the atmosphere model of Venus with heated surface and "cold" cloud layer with temperature assumed to be in the range $270 \pm 30^{\circ}$ K.

According to [9, 10] the observation data of the phase course of Venus' brightness temperatures in 10, 3.2 and 0.8 cm may be represented in the following form

$$\begin{aligned} T_{\text{я}}(10) &= 622 + 41\cos(\Phi \pm 21^{\circ}); \\ T_{\text{я}}(3.2) &= 621 + 73\cos(\Phi \pm 17^{\circ}.7); \\ T_{\text{я}}(0.8) &= 427 + 41\cos(\Phi - 21^{\circ}). \end{aligned} \qquad (1)$$

The closeness of the mean values of radiobrightness temperatures in the 3.2 and 10 cm wavelengths allows us to assume a low value of atmosphere absorption in that portion of the spectrum, and to estimate by the same token the value of the radiobrightness temperature of planet's surface.

The value of the radiobrightness temperature of the dark side, averaged along the disk, is taken to be 548° in accord with (1), and that of the lit side at 694° K.

The difference in spread of the values of radiobrightness temperature in 3.2 and 0.8 cm wavelengths is used for the determination of atmosphere absorption in 0.8 cm (it is assumed that the temperature of Venus' cloud layer responsible for the emission in the 8 mm wavelength depends little on the value of the phase angle).

Taking into account the above considerations, the ratio of the fluctuation ranges of the observed brightness temperature in 3.2 and 0.8 cm may be represented in the form

$$\frac{\Delta T_{\text{я}}(0.8)}{\Delta T_{\text{я}}(3.2)} = \frac{(T_{\text{яо}} - T_{\text{ян}}) \int\limits_0^{\pi/2} e^{-\tau(0.8)/\cos\varphi} \cos\varphi \sin\varphi \, d\varphi}{(T_{\text{яо}} - T_{\text{ян}}) \int\limits_0^{\pi/2} e^{-\tau(3.2)/\cos\varphi} \cos\varphi \sin\varphi \, d\varphi} \simeq 2E[\tau(0.8)], \qquad (2)$$

where $T_{\text{яо}}$ is the value of the radiobrightness temperature of the lit side of Venus, averaged along the disk and $T_{\text{ян}}$ is the same for the night side;

$$E(\tau) = \int_0^1 e^{-\tau/x} x\,dx$$

is the tabulated function of integral absorption τ. The value of the integral absorption in 0.8 cm is determined, according to (2) in the form

$$\tau(0.8) = \arg E\left[\frac{\Delta T(0.8)}{\Delta T(3.2)}\right]. \qquad (3)$$

Substituting into (3) the values of variation amplitudes of radiobrightness temperatures according to observation data of the phase course (1), we obtain the estimate of the integral absorption as being $\tau(0.8) = 0.32$.

The obtained estimate of the value of integral absorption in 8 mm is extrapolated in the microwave band in the asssmption that the absorption is determined by a cloud layer consisting of water droplets.

Admitting that the elasticity of water vapors in the layer does not exceed 5 mb, and disregarding the contribution from selective absorptions, we shall utilize the extrapolation correlation in the form

$$\tau(\lambda) = \tau(\lambda_0)\frac{C(\lambda)}{C(\lambda)_0}\frac{\lambda_0}{\lambda}; \qquad (4)$$

$$\tau(\lambda) \equiv \frac{C(\lambda_0)}{\lambda_0}\int_{H_1}^{H_2} W dl, \qquad (5)$$

where W is the volume content of droplet moiture; H_1, H_2 are the heights of the upper and lower edges of the clouds;

$$C(\lambda) = \frac{\varepsilon''(\lambda)}{[\varepsilon'(\lambda)+2]^2+[\varepsilon''(\lambda)]^2}. \qquad (6)$$

The values of the true $\varepsilon'(\lambda)$ and imaginary $\varepsilon''(\lambda)$ parts of the dielectric constant are determined by the well known formulas:

$$\varepsilon'(\lambda) = \varepsilon_\infty + \frac{\varepsilon_0-\varepsilon_\infty}{1+y^2}, \quad \varepsilon''(\lambda) = \frac{\varepsilon_0-\varepsilon_\infty}{1+y^2}y, \qquad (7)$$

where ε_∞ is the value of the dielectric constant in the region $\lambda < c\tau_{p_0}$;

TABLE 1

T° C	+20	+18	+10	0	−5	−10	−20
ε_0	80	81	84	88	90	92	96
$\Delta\lambda_{[см]} = 2\pi c\tau_p\left(\frac{\varepsilon_0+2}{\varepsilon_\infty+2}\right)$	1.53	1.66	2.24	3.59	4.36	5.39	7.40
$\tau_p[сек]$	$7.4\cdot10^{-13}$	$8\cdot10^{-13}$	$1.01\cdot10^{-12}$	$1.6\cdot10^{-12}$	$1.95\cdot10^{-12}$	$2.4\cdot10^{-12}$	$3.4\cdot10^{-12}$

ε_0 is the value of the dielectric constant in the region of zero frequencies;

$$y = 2\pi \frac{c}{\lambda} \tau_p \left(\frac{\varepsilon_0 + 2}{\varepsilon_\infty + 2} \right);$$

while τ_p is the relaxation constant. According to data brought out in [8] , for temperatures, exceeding the melting temperature, the constant ε_∞ does not practically depend on temperature, whereas the constants ε_0 and τ_p vary substantially with temperature change.

The values of the Debye constants in the supercooling region were obtained by way of extrapolation of the available data to temperature range below the melting temperature.

The values of the Debye constants according to data of [11] for the temperature range above the melting point and the extrapolated values for the temperature range below the melting point are compiled in Table 1.

TABLE 2

λ/λ_0	0.4/0.8	1.6/0.8
$k(\lambda, \lambda_0)$	2.7	3.2
$k^*(\lambda, \lambda_0)$	2.4	3.3

The experimental verification of the results of extrapolation was made at radiometric measurements of absorption in the terrestrial atmosphere clouds in the wavelengths 0.4, 0.8, 1.6 and 3.2 cm.

The data of experimental estimates of the values of relative absorptions taking into account the measurement errors agree well with the values of absorption computed by (4) and utilizing the values of Table 1.

The computations of the values of absorption in 0.4 and 1.6 cm waves, referred to the absorption in 0.8 cm, and the corresponding experimental data for the cloud layer at temperature of — 5° C, are compiled in Table 2.

$$k(\lambda, \lambda_0) = \frac{C(\lambda)}{C(\lambda_0)} \frac{\lambda_0}{\lambda}$$

are the computed values of relative absorptions;

$$k^*(\lambda, \lambda_0) = \frac{\tau(\lambda)}{\tau(\lambda_0)}$$

are the experimental values of relative absorptions.

The absorption spectrum of Venus' cloud layer, obtained with extrapolation by (4) of the value of absorption in 0.8 cm wave in the assumption that the temperature of the layer is 260 K, is plotted in Fig. 1; the values of the estimates of integral absorption according to measurement data of radiobrightness temperature of Venus' night side for parameters corresponding to the selected model, are noted also in Fig. 1 for comparison.

The discrepancy in the estimates of absorption does not exceed 1 db.

The estimates of the temperature of the absorbing layer in the atmosphere of Venus can be made more precise by comparing the computed and the experimental values of the spectrum of radiobrightness temperatures of the night side of Venus.

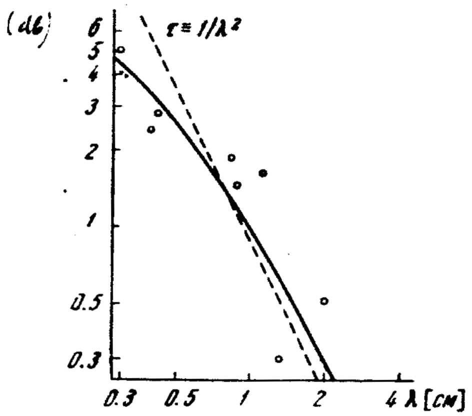

Fig. 1. - Extrapolated spectrum of integral absorption in a cloud layer consisting of supercooled water droplets.

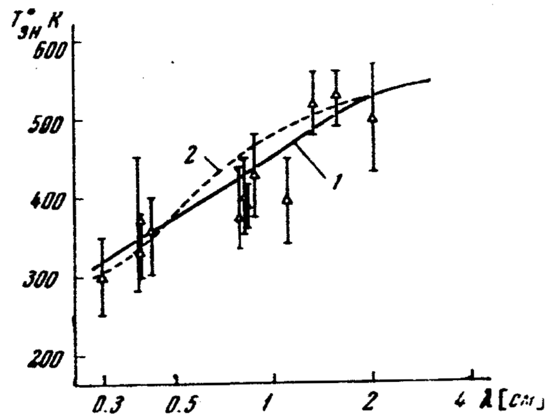

Fig. 2. - Computed and experimental values of the spectrum of radiobrightness temperatures of the night side of Venus: 1 — $T_o = 260^o$ K; 2 — $T_o = 280^o$ K.

We shall make use for the computation of the spectrum of radiobrightness the radiation transfer correlation in the form

$$T_{н}(\lambda) = T_{нн}2E[\tau(\lambda, T_0)] + T_0\langle 1 - 2E[\tau(\lambda, T_0)]\rangle. \qquad (9)$$

where $T_{ЯН}$ is the value of radiobrightness temperature on the night side of the surface of Venus , averaged along the disk; T_o is the temperate of the isothermic absorbing layer; $E[\tau(\lambda, T_0)]$ is the integral function, see (2). The dependence of the form of the function of integral absorption on the temperature of the absorbing layer allows the estimate of the value of layer's temperature from the condition of agreement of experimental and computation data.

Thus, Fig. 2 shows that a satisfactory agreement of computed and experimental data is reached for water-droplet absorbinglayer model with temperature 250 ÷ 260° K, while the computed values of radiobrightness temperatures for the modelewith layer's temperature exceeding 270 ° K, are deflecting noticeably frc from the experimental data (Note that in cupercooling contitions at temperature of the layer of about 260° K the value of the constant relaxation of water droplets constitutes, according to extrapolation data, $2.5 \cdot 10^{-12}$ sec, which does not contradict the conclusion about the anticipated parameters of the cloud layer brought out in [10]).

The obtained data on the value of integral absorption allows to estimate the content in droplet moisture in the atnosphere of Venus. According to (5) we have

$$W_{\Sigma} = \int_{H_1}^{H_2} W\,dH \equiv \frac{\tau(\lambda)\lambda}{C(\lambda)}. \qquad (10)$$

Substituting in (10) the value $\imath(\lambda)$ in Fig. 1, we obtain the estimate of the content of droplet moisture in the form

$$W\left[\frac{g}{cm^2}\right] \quad 0.1 \div 0.3\, g/cm^2,$$

which, for clouds with water tenor to 1 g/cm^3 corresponds to layer thickness up to 3 km.

The anticipated correction to the estimate brought up of moisture content on account of crystalline structure of cloud layers does not exceed 20 ÷ 30%.

It should be noted that the data brought out are obviously insufficient for an unambiguous conclusion on the nature of Venus' cloud layer; further detailed investigations of emission spectrum peculiarities are required, including the observations of the phase course pattern in the entire microwave band.

***** THE END *****

Institute of Radioengineering and Electronics
of the USSR Academy of Sciences

Received on
1 April 1965

Contract No. NAS-5-9299
Consultants & Designers, Inc.
Arlington, Virginia

Translated by ANDRE L. BRICHANT
on 15-16 March 1966

REFERENCES

1.- B. LYOT.- Ann. Observ. Men., 8, 66, 1927.
2.- W. SINTON.- Comp. on Planet. Atmosph., New York, 1962.
3.- A. H. BARRETT.- Astrophys. J., 133, 281, 1961.
4.- V. I. MOROZ.- Astronom. Zhurnal, 40, 144, 1963.
5.- A. E. SALOMONOVICH.- Radiofizika, 7, 51, 1964.
6.- A. H. BARRETT.- Space Science Review, 3, 109, 1964.
7.- A. D. KUZ'MIN.- Radiofizika, 8, No. 6, 1964.
8.- J. POLLACK, C. SAGAN.- The Microwave Phase Effect on Venus, Preprint, 1965.
9.- F. D. DRAKE.- Astronom. J., 69, 62, 1964.
10.- A. E. BASHARINOV, YU. N. VETUKHOVSKAYA, A. D. KUZ'MIN et AL. Astronom. Zh., 41, 707, 1964.
11- D. E. KERR.- Propag. of Short Radio Waves, New York, 1949.

DISTRIBUTION

GODDARD SPACE F.C.

100	Clark, Townsend
110	Stroud
400	Bourdeau
610	Meredith, Seddon
611	McDonald
	Abraham, Boldt
	VKB, Williams
	Se rlemitsos
612	Heppner
	Ness
613	Kupperian
	Boggess III
	Dunkelman
	Milligan
	Donn
	Hallam
614	White
	Frost, Wolff
615	Bauer
	Goldberg
	Stone
640	Hess
	Mead
	Cameron
	Burley
630	GI for SS (3)
620	Spencer
252	Library
256	Freas

NASA HQS

SS	Newell, Naugle
SG	Mitchell
	Schardt, Schmerling
	Roman, Smith
	Dubin
SL	Liddel
	Brunk
	Fellows
	Hipsher
	Horowitz
SM	Foster
	Gill
RR	Kurzweg
RTR	Neill
ATSS	Schwind
	Robbins
WX	Sweet

ARC

Sonett
Library

La R C

160	Adamson
235	Seaton
185	Weaterwax

M. I. T.

Barrett

U. MICH.

Haddock

U. IOWA

Van Allen

U. C. BERKELRY

Field

SWCAS

Johnson

J P L

Newburn
Kaplan
Sagan